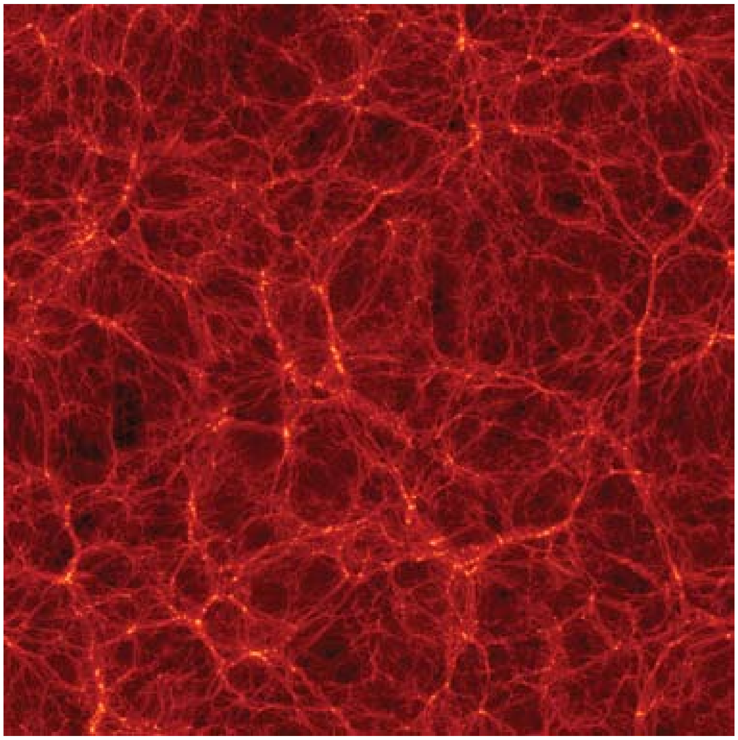
High-Resolution Simulations of Galaxy and Cosmological Structure Formation

A key challenge in astronomy is to explain how structures in today's universe formed within the Lambda cold dark matter (CDM) framework, and to test these new theories against observational evidence from sources such as NASA's Hubble, Chandra, Spitzer, and Fermi space telescopes. The theories we are developing and simulating help predict and interpret observations, and design future missions such as the James Webb Space Telescope and Joint Dark Energy Mission. We are providing the main theoretical support for the Deep Extragalactic Evolutionary probe (DEEP) and All-wavelength Extended Groth strip International Survey (AEGIS), which incorporate extensive data from NASA's space observatories.

We are conducting high-resolution hydrodynamic simulations of mergers of gas-rich disk galaxies, which may form many of the fast-rotating elliptical galaxies found in our universe. We have also created an analytical model that correctly predicts properties of such elliptical galaxies, allowing us to interpolate between simulated cases and extrapolate beyond them. This work lets us calculate the entire evolving population of early-type galaxies. We are also doing hydrodynamic simulations of cold gas inflows and multiple mergers at high redshifts $z > 2$, which may form about 25% of elliptical galaxies classified as "slow rotators." Finally, we are running large dissipationless simulations, including a constrained realization of our local region of the universe and our Bolshoi simulation of a volume approximately 1 billion light years on a side. The latter uses the new 5th-year cosmological parameters from the Wilkinson Microwave Anisotropy Probe (WMAP) and has mass and force resolution an order of magnitude better than the European Virgo Consortium's Millennium Run.

The supercomputers at Ames' NASA Advanced Supercomputing (NAS) facility have been extremely helpful in running dissipationless and hydrodynamic simulations of large-scale structure evolution and hydrodynamic simulations of galaxy mergers, including development and use of our Sunrise code. NAS' Schirra supercomputer nodes, with 16 IBM Power5 processors addressing 32 gigabytes of RAM, has been essential for our galaxy formation simulations. Collaboration with the NAS Visualization Group has been crucial in visualizing and interpreting the results of these simulations.

These visualizations are helping astronomers and the wider public (e.g., planetarium visitors) to understand the evolving cosmos. Primary funding for this research comes from NASA's Astrophysics Theory and Fundamental Physics Program, with additional funding from Spitzer and Hubble theory grants.



Final timestep ($z = 0$) of the Bolshoi Simulation (cosmological ΛCDM simulation using 8 billion particles with WMAP5 parameters in a volume 250 h-1 Mpc on a side), showing a slice 10 h-1 Mpc thick by 250 h-1 Mpc square.

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